Recommended
Mix Design Guidelines
For
Cold Recycling Using Emulsified Asphalt Recycling Agent
CR201

Revised: 12/22/2016

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NOTICE

It is not intended or recommended that these guidelines be used verbatim within a specification. Owner Agencies should use them to help establish their particular project specification. Owner Agencies should understand that all geographical areas and pavement rehabilitation/preservation projects are unique and the availability of materials and equipment may vary as well. ARRA assumes no liability for utilization of these guidelines by any individual or entity. Contact ARRA for answers to questions and for a list of ARRA member Contractors and Suppliers.

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1. General

A mix design with emulsified asphalt shall be performed with the materials to be encountered during construction of the Cold Recycling (CR) which includes Cold In-place Recycling (CIR) or Cold Central Plant Recycling (CCPR). When the materials change significantly additional mix designs shall be performed to establish representative mixes for the entire job. Representative samples of the asphalt pavement shall be obtained from the roadway for CIR or from a stockpile for CCPR and delivered to an AASHTO accredited or Owner Agency approved laboratory experienced in cold recycled mix designs using emulsified asphalts, where the asphalt pavement samples shall be crushed, if required, and mixed with emulsified asphalt and additives, as necessary and then, at a minimum, tested in accordance with the procedures and requirements of **Table 1** and the additional procedures and requirements of **Table 3**, when desired.

User Notes: Sampling and mix designs for CR are different than for heated asphalt mixtures (HMA and WMA), and not just in the tests that are performed or the properties that are targeted. HMA and WMA designs are based on blending two to five aggregates in certain proportions to obtain desired outcomes, such as air voids and voids in mineral aggregate. If aggregate properties change through a season or year to year, the blend is adjusted at the plant or a new design is performed. Making adjustments to achieve target properties is not only possible but even required. With CR, however, the nature of the construction process does not allow for quick adjustments. Therefore, understanding the variability of the road and designing for it prior to construction is important.

The mix design parameters provided in Table 1 are minimum parameters and should be parts of all cold recycle mix designs. The optional high and low temperature validation test parameters provided in Table 3 are recommended when an Owner Agency wants a higher level of reliability or when the desired level of risk, traffic, and length of the project justify the increased cost.

The more that is known about the roadway and terrain the better one can deal with any design and constructability issues that may arise. A site analysis captures many elements that can affect the end performance of cold recycled pavements that a mix design cannot. For example, a mix design will not account for a soft or failing base, nor will it take into account the fact that sections of the roadway only receive two hours of sunlight a day. The sampling crew should describe all abnormal occurrences so as to provide the engineer a thorough understanding of in-situ conditions.

2. Sampling Procedures for In-place Materials

2.1 Sampling of Reclaimed Asphalt Pavement Materials

Samples of asphalt pavement shall be obtained from the areas to be recycled. The purpose of the samples is for mix design, and to determine if the thickness of the existing pavement is suitable for the recycle depth proposed.

User Note: The level of sampling for a cold recycled project is dependent on many factors including the selected reliability of the design, level of risk, length of the project and testing required. The composition of the whole project is important. Samples for mix design and analysis are required for each major difference in observed material types. For example, if one area is composed of aged, oxidized, dense graded HMA overlay and another area is composed of an open graded HMA on top of a less distressed, dense graded HMA, two sets of samples are recommended for design and analysis. Another example would be if one area contains a single chip seal and another has multiple seals.

For CIR and CCPR where the project schedule does not permit obtaining samples from the stockpile, all

samples shall be obtained from the full depth of the pavement to be recycled. Additional samples shall be obtained and separated for individual mix design analysis if visual observations indicate greater variation in materials within a segment (i.e. large patches, high binder content mixes). The depth of asphalt layers to aggregate base, subgrade or concrete; thickness of individual layers; and type of material in the projected recycled depth shall be determined. If differing material types are observed, samples shall be obtained at each differing material type location and a mix design shall be conducted for each material type.

Samples may be obtained as cores or milled RAP from the areas to be recycled.

Core samples shall be obtained to the underlying base or subgrade soil. If a core breaks off prior to penetrating the underlying materials, coring shall continue to the bottom of the pavement for thickness measurement purposes. On retrieval, each core shall be measured to the nearest 1/8-inch (3-mm) and then placed in a separate container and labeled. A coring log summarizing the date, station, offset, and core thickness shall be recorded for each core location and provided to the mix design laboratory.
Milling of material may be conducted provided the cold planer (milling machine) produces a consistently graded RAP similar to the RAP gradation expected during recycling operations. Only millings that represent the pavement to be recycled shall be collected. If a portion of the existing pavement surface is planned to be milled and removed during construction, the pavement shall be milled in a similar manner and removed prior to milling for sampling purposes. Milling and sampling shall only be to the planned recycle depth. The material may be obtained from one test location for each mix design. For example, if a pavement change exists within the limits of the roadway, one test location should be designated for each area.

User Note: If the project calls for 2 inches (50 mm) of existing pavement to be milled and removed, then the top 2 inches (50 mm) of pavement should be milled and removed prior to milling for sampling purposes. CR treatments are usually specified as a milling depth rather than a compacted layer thickness, whereas CCPR depths are normally specified as final compacted thickness. CR materials will not compact to the original milled thickness. This difference in thickness is referred to as a "fluff factor." Typical fluff factors are 10-15% but vary due to materials, methods and environmental conditions.

Sufficient usable material, up to 350 lbs. (175 kg) shall be obtained. Usable material is defined as the length in the core that corresponds to the recycling depth from the existing pavement surface or the recycle depth after pre milling. Cores shall be cut at the planned recycling depth and only that portion to be recycled shall be used for mix design purposes. Equation [1] may be used to determine the number of cores needed for each 350 lbs. (175 kg) per mix design at a core unit weight of 145 pcf (2.324 g/cm^3). For different mix design weight requirements or unit weights of cores, the number of cores should be proportioned. When using equation [1] only consider the depth of recycle. Remaining material below the depth of recycle shall be trimmed and not used for mix design purposes.

<u>English Units</u>

$$CMD = [5{,}311] / [(D^2)\,(CRMD)] \qquad [1a]$$

where:

CMD = number of cores per mix design
D = core diameter (in)
CRMD = cold recycle milling depth (in)

<u>SI Units</u>

CMD = [83,881,233] / [(D^2) (CRMD)] [1b]

where:

CMD = number of cores per mix design
D = core diameter (mm)
CRMD = cold recycle milling depth (mm)

User Note: For example, if a 3-inch (75-mm) depth of recycle is proposed and the pavement has a unit weight of 145 pcf (2.324 g/cm^3) then the following number of 6-inch (150-mm) diameter cores are needed:

CMD = [5,311] / [$(6)^2$(3)] = 49.2 or 49 cores

CMD = [788,881,233] / [$(150)^2$(75)] = 49.7 or 50 cores

Conversely, if the actual pavement is thinner than the recycle depth additional cores are needed. A weighted average of the thickness of the milled pavement can be used with the above equations to determine the number of cores.

Cores shall be obtained using a pattern that results in a representative sample of the pavement to be recycled including at or near lane lines, within and between wheel paths, at the pavement edge and within shoulders if shoulders are to be recycled. The roadway shall be sampled in accordance with staggered or offset sampling (as illustrated in **Diagram 1a)** or crossroad sampling with no offset (as illustrated in **Diagram 1b)**.

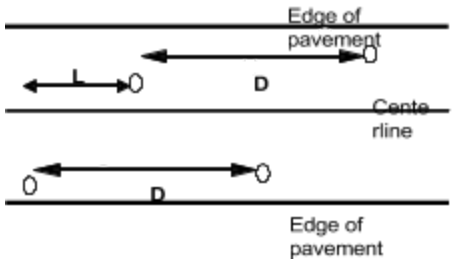

Diagram 1a – Staggered (offset) sampling. Diagram 1b – Crossroad sampling.

The minimum rate of coring shall be as follows:

D - _____ mile maximum (___ km)
L – _____ mile maximum (___km)
At least ___% of the cores shall be in the shoulder, if it is getting recycled, or within 3 feet (1 m) of gutter.
At least ___% of the cores shall be on or within 3 feet (1 m) of centerline.

User Note: Select the type of sampling pattern preferred. With staggered or offset sampling the cores are obtained in one lane at a prescribed sampling rate of D and offset a distance L in the adjacent lane. With

crossroad sampling, all cores across both lanes are obtained at a prescribed sampling rate of D with no offset between lanes.

Typically L=D/2

User Note: The rate of coring is also based on determining the uniformity of projects. Unless overridden for a particular project the following guidelines should be a **minimum:**

Highways or Airports

D – 1 mile maximum (1.6 km)
L – 0.5 mile maximum (0.8 km)
At least 15% of the cores should be in the shoulder if the shoulder is getting recycled.
At least 25% of the cores should be on or within 3 feet (1 m) of centerline.

Arterial and Industrial Streets

D – 2,000 feet maximum (600 m)
L – 1,000 feet maximum (300 m)
At least 25% of the cores should be in the shoulder if it is getting recycled or within 3-feet (1 m) of gutter.
At least 25% of the cores should be on or within 3 feet (1 m) of centerline.

Residential Streets

Streets less than 250 feet long (75 m), one core when grouped with other streets to obtain the quantity of material required for mix design.

Streets 250 feet to 500 feet (75 m to 150 m) long, two cores when grouped with other streets to obtain the quantity of material required for mix design. One within 3 feet (1m) of gutter the other within 3 feet (1 m) of centerline.

Streets over 500 feet (150 m) long, three cores when grouped with other streets to obtain the quantity of material required for mix design. One within 3 feet of gutter (1 m), one within 3 feet (1 m) of centerline, the third between the two.

2.2 Safety

Proper personal protective equipment (PPE) shall be used on all sampling projects. Only personnel trained to operate core drills or milling equipment shall perform sampling operations. Traffic control shall be performed by qualified, experienced personnel.

2.3 Shipping

Samples shall be shipped in sturdy containers (plastic or metal buckets or small strong plastic tubs) or on pallets with each sample clearly marked. Cardboard boxes shall not be used. A copy of the sampling log, protected in a sealed container, shall be included with shipment of samples.

2.4 Filling Sample Holes

A high quality cold patch material shall be used to fill core or milling holes. The cold mix shall be compacted flush with a tamping rod, sledge or Marshall hammer. After sampling and filling the holes, the roadway shall be cleaned of all loose debris.

3. Stockpile Sampling for CCPR

If sampling is not required for in-place materials, RAP samples for CCPR may be obtained from the stockpile to be used for construction of the CCPR material. Sufficient usable RAP, up to 350 lbs. (175 kg) shall be obtained for the mix design.

3.1 Stockpile Sampling of Reclaimed Asphalt Pavement Materials

To ensure the stockpile samples accurately represent the materials in the stockpile, the crust of the stockpile shall be removed in accordance with AASHTO T 168 section 5.2.7 and then the RAP sampled in accordance with AASHTO T 2 Appendix X1.2.

3.2 Safety

Proper personal protective equipment (PPE) shall be used on all sampling projects.

3.3 Shipping

Samples shall be shipped in sealed containers (plastic or metal buckets or small strong plastic tubs) with each sample clearly marked. Cardboard boxes shall not be used. A copy of the sampling log, protected in a sealed container, shall be included with shipment of samples.

4. Emulsified Asphalt Cold Recycle Mix Design

A mix design shall be performed with the materials to be encountered during construction of the cold recycling.

4.1 Testing Parameters

The mix design for emulsified asphalt shall meet the minimum recommended parameters listed in Table 1.

TABLE 1 – MINIMUM COLD RECYCLING MIX DESIGN REQUIREMENTS FOR EMULSIFIED ASPHALT

Test Method	Criteria	Property
Asphalt Content of RAP [a] AASHTO T 308 (ASTM D6307)	Report Only	Quantity of Existing Binder
Gradation of Unextracted RAP [a] AASHTO T 11[b] & T 27 (ASTM C117[b] & C136)	1.25-inch (31.5-mm) Maximum Per Table 3	Maximum Particle Size
Bulk Specific Gravity of Compacted, Cured Specimens [c] AASHTO T 166 (ASTM D2726)	Report Only	Density as Compacted
Maximum Theoretical Specific Gravity [d] AASHTO T 209 (ASTM D2041)	Report Only	Maximum Specific Gravity
Air Voids of Compacted, Cured Specimens [c,d] AASHTO T 269 (ASTM D3203)	Report Only – Recycling agent content should not be adjusted to meet an air void content.	Compacted Air Voids
Either		
Indirect Tensile Strength [c,e] AASHTO T 283 (ASTM D4867)	Minimum 45 psi (310 kPa) [f,g]	Cured Strength
Or		
Marshall Stability [c,e]	Minimum 1,250 lbs. (5,560 N) [g]	Cured Stability

AASHTO T 245 (ASTM D6927)		
Tensile Strength Ratio/Retained Marshall Stability based on Moisture Conditioning [c,e,h] AASHTO T 283 (ASTM D4867) AASHTO T 245 (ASTM D6927)	Minimum 0.70 [i]	Resistance to Moisture Induced Damage
Raveling Test of Cold Mixed Bituminous Mixtures [j] ASTM D7196	Maximum 7.0% loss [j]	Resistance to Raveling
Ratio of Residual Asphalt to Cement	Minimum 3.0:1.0 (refer to section 4.3.1 and 4.3.2 of CR101)	Prevent Rigid Behavior
RAP Coating Test [k] AASHTO T 59	Minimum Good	Coating of Binder
Maximum Emulsified Asphalt Heating Temperature	Report Only (Obtained from Supplier)	Maximum Heating Temperature
PG Grade of Recycling Agent AASHTO M 320	Select low temperature PG grade of recycling agent to meet or be one grade higher that the requirements for location of project and depth in pavement structure. [l]	Resistance to Low Temperature Cracking

NOTES:

[a] **For cores from in-place materials,** a laboratory milling machine shall be used to model the gradation expected during recycling. For CCPR where samples are obtained from the preprocessed stockpiles, the samples shall be used directly. If additional processing of CCPR stockpiles will be required, such as scalping or crushing/ screening, the samples shall be processed in a similar fashion.

As an alternative, mix designs at two separate gradations shall be performed by screening and crushing with a laboratory crusher and then recombining the RAP in accordance with the gradation criteria of **Table 2**.The selected gradations shall be chosen to match the expected gradation as closely as possible. If the CR is to be conducted using cold planers (milling machines) operating in a down cutting mode then the fine and medium gradation shall be used. For cold planers operating in the up cutting mode the medium and coarse gradation shall be used. For low volume roads, and at the discretion of the Owner Agency, the medium gradation only may be used. The entire sample material shall be crushed to 100% passing the 1.25-inch (31.5- mm) sieve; however, only the material passing the 1-inch (25-mm) sieve shall be used to manufacture test specimens with 4-inch (100-mm) molds. RAP shall be dried to a constant mass at 104 ± 4 °F (40 ± 2 °C) prior to mixing.

TABLE 2- COLD RECYCLING GRADATION REQUIREMENTS

Sieve Size	Fine Gradation	Medium Gradation	Coarse Gradation
	Percent Passing		
1.25" (31.5 mm)	100	100	100
3/4" (19 mm)	95 - 100	93 - 97	83 – 87

No. 4 (4.75 mm)	60 - 70	48 - 52	38 – 42
No. 30 (600-µm)	20 - 30	8 - 12	3 – 7
No. 200 (75-µm)	1 - 7	1 – 3	0.5 – 2

[b] If a washed sieve analysis is desired, the samples should be dried to a constant mass at 104 °F (40 °C) prior to performing the sieve analysis.

User Note: Drying to a constant mass at 104 °F (40 °C) could take several days.

[c] Mixing of test specimens shall be performed either manually, with a mechanical bucket mixer, with a laboratory size pugmill, or a combination thereof. The RAP shall be thoroughly mixed with water first, then mixed with the recycling agent. Moisture that is expected to be added at the milling head during construction, typically 1.5 to 3.0%, shall be used. A minimum of three emulsified asphalt recycling agent contents that bracket the estimated recommended recycling agent content shall be selected. Emulsified asphalt shall be drizzled in at the appropriate rate. If any recycling additives are proposed for the mixture they shall be introduced to mixing in a similar manner that they will be added during field production. After adding the emulsified asphalt and any recycling additives, the entire mixture shall be mixed at room temperature 77 ± 9 °F (25 ± 5 °C). One specimen shall be mixed at a time. Mixing time shall not exceed 60 seconds.

Specimens shall be compacted at room temperature 77 ± 9 °F (25 ± 4 °C) after mixing. Specimens for Marshall testing shall be compacted to 2.5 ± 0.1 inch (63.5 ± 2.5 mm) tall, 4 inches (100 mm) in diameter, using either 75 blows per side by a Marshall hammer or with 30 gyrations using a Superpave gyratory compactor (SGC) at 1.25° angle, 87 psi (600 kPa) stress. Indirect tensile strength specimens shall be compacted using the SGC to 6-inch (150-mm) diameter and 3.7 ± 0.1 inch (95 ± 5 mm) tall. Molds and Marshall compaction hammer shall not be heated. A total of 6 specimens at each emulsified asphalt recycling agent content shall be prepared for indirect tensile strength testing or Marshall stability testing, 3 for cured specimens and 3 moisture condition cured specimens. If paper disks are used, the paper disks shall be placed on the top and bottom of the specimen before compaction and shall be immediately removed after compaction. Specimens shall be extruded from molds after compaction so as not to damage the specimens. Specimen heights shall be determined according to AASHTO T 245 (ASTM D6927) or may be obtained directly from the readout if the SGC is used.

After compaction, specimens shall be placed in a forced draft oven with ventilation on sides and top. Each specimen shall be placed in a small container to account for material loss from the specimens. Specimens shall be cured at 140 ± 2 °F (60 ± 1 °C) to constant weight for at least 16 hours but not more than 48 hours. Constant weight is defined as 0.05% change in weight in 2 hours. After curing, specimens shall be cured at ambient temperature a minimum of 12 hours to a maximum of 24 hours.

[d] Two additional specimens, mixed in accordance with **note c** above, shall be prepared for Theoretical Maximum Specific Gravity according to AASHTO T 209 (ASTM D2041) with the exception that loose RAP mixtures shall be cured in an oven at 140 ± 2 °F (60 ± 1 °C) to constant weight for at least 16 hours but not more than 48 hours. Constant weight is defined as 0.05% change in weight in 2 hours. Agglomerates which will not easily reduce with a flexible spatula shall not be broken. Both specimens shall be tested at the highest recycling agent content in the design and back calculated for the lower recycling agent contents. The optional dry-back procedure of AASHTO T 209 (ASTM D2041) may be required to account for the effect of uncoated particles.

[e] For indirect tensile strength testing, compacted and cured specimens shall be brought to test temperature by placing each specimen in a leak-proof bag and submerging in a water bath at 77 ± 2 °F (25 ± 1 °C) for 30-45 minutes immediately prior to testing in accordance with AASHTO T 283 (ASTM D4867). Marshall stability shall be determined using AASHTO T 245 (ASTM D6927) at 104 ± 2 °F (40 ± 1 °C) after 2-hour temperature conditioning in a forced draft oven or by placing specimens in a leak-proof bag in a water bath at 104 ± 2 °F (40 ± 1 °C) for 30-45 minutes immediately prior to testing. This testing shall be performed at the same time that moisture-conditioned specimens are tested.

[f] When recycling RAP with rounded aggregate, a sandy gradation, or softer binders (recovered penetrations greater than 30) 45 psi (310 kPa) may not be achievable without a recycling additive. In such instances a minimum of 34 psi (225 kPa) may be acceptable. The Owner Agency will determine whether the specification needs to be reduced or whether an additive shall be used according to the pertinent additive sections of *CR101 - Construction Guidelines for Cold In-Place Recycling Using Bituminous Recycling Agents* and *CR102 - Construction Guidelines for Cold Central Plant Recycling Using Bituminous Recycling Agents*.

[g] Minimum values to be obtained for mix design stage only; for field construction, refer to *CR101* and *CR102*.

[h] Moisture conditioning shall be conducted on 3 compacted, cured specimens at each recycling agent content by applying a vacuum of 2 psi to 10 psi (13 to 67 kPa) absolute pressure 10 to 26 inches (254 to 660 mm) of Hg partial pressure for a time duration required to vacuum saturate specimens to 55 to 75 percent. Percent saturation shall be calculated by comparing saturated surface dry mass with dry mass in air. For tensile strength ratio testing (AASHTO T 283 or ASTM D4867), specimens shall then be submerged in a 77 ± 2 °F (25 ± 1 °C) water bath for 24 hours and indirect tensile strength determined in accordance with AASHTO T 283 (ASTM D4867) immediately after removal from the water bath. For retained Marshall stability testing, specimens shall be submerged in a 77 ± 2 °F (25 ± 1 °C) water bath for 23 hours followed by a one hour soak at 104 ± 2 °F (40 ± 1 °C) and Marshall stability determined in accordance with AASHTO T 245 (ASTM D6927) immediately after removal from the water bath. Retained stability shall be defined as the average moisture conditioned specimen strength/stability divided by the average dry specimen strength/stability.

[I] The Tensile Strength Ratio/Retained Stability Ratio may be reduced to 0.60, provided the moisture condition indirect tensile strength or conditioned Marshall stability exceeds the minimum dry strength/stability requirement.

[J] Two specimens shall be prepared in accordance with ASTM D7196 at the actual or medium RAP gradation and optimum emulsified asphalt recycling agent content for that gradation. Compaction temperature shall be 77 ± 9 °F (25 ± 5 °C). Immediately after compaction specimens shall be conditioned at 50 ± 2 °F (10 ± 1 °C) at 50% relative humidity for 4 hours ± 5 minutes. Procedures and calculations in accordance with ASTM D7196 shall be followed. The average percent mass loss of the two specimens shall be reported regardless if the replicate samples differ by more than 0.5%. ASTM D7196 is not required for a CCPR mix that will be used as a stockpile mixture.

User Note: A maximum loss of 7.0% has been found generally acceptable to prevent raveling although mixtures placed at warmer temperatures with higher percent loss in the laboratory have performed satisfactorily. Resistance to raveling is a function of emulsified asphalt recycling agent content, emulsified asphalt formulation and environmental factors that control breaking and curing times. Increased emulsified asphalt recycling agent content typically improves performance in the raveling test. Environmental factors that affect breaking and curing are temperature, wind speed and relative humidity. An increase in the

magnitude of any one of the three environmental factors will speed breaking and curing and improve raveling resistance in the field. At in situ conditions considerably warmer and drier than test conditions, less emulsified asphalt recycling agent is often required to resist raveling in the field. If emulsified asphalt recycling agent contents are not reduced accordingly, flushing and mix instability could occur, especially with higher traffic. The optional high temperature validation procedure will quantify the effect of higher temperatures on raveling performance.

The use of the raveling test in combination with other tests in this procedure may be protected by one or more of the following US patents 6,599,057, 7,275,890, and 7,455,476. For more information, contact Road Science at www.roadscience.net or call 918-960-3800. Alternatively, do not perform the raveling test or replace it with an alternate test.

[k] Modify ASSHTO T 59 using jobsite RAP, emulsified asphalt recycling agent and water application rates that have been determined in the mix design.

[l] In selecting the PG grading for the emulsified asphalt to be used, the Owner Agency should consider that the actual binder will be softer than the binder specified since the PG grading is based on a rolling thin film oven test that simulates the heating and stiffing of the binder during the hot mix production. In CR that heating process does not occur.

4.2 Optional Testing Parameters for Emulsified Asphalt Recycling Agents

For a higher reliability mix design, the following additional test parameters shall be conducted:

User Note: The procedures provided in Table 3 are recommended for inclusion when an Owner Agency wants a higher level of reliability or when the desired level of risk, traffic and length of the project justify the increased cost.

***High Temperature Validation*:** At higher temperatures RAP will be less viscous and will compact to a higher density. At higher density less recycling agent is often required to pass the mix design tests listed in Table 1. If recycling agent contents are not reduced accordingly, flushing and or mix instability could occur, especially with higher traffic levels. The optional high temperature validation procedures will quantify the effect of higher temperatures and lower recycling agent contents on performance.

***Evaluation of Existing Binder*:** The existence of soft (high penetration) or high asphalt cement content recovered binders can impact mixture performance and can make it difficult to meet minimum mix design requirements. Knowing recovered binder properties provides the engineer, Contractor and Owner Agency with valuable information for use in evaluating mix design results, selecting recycling agents and additives and alerting the Contractor to constructability issues.

TABLE 3 – RECOMMENDED OPTIONAL COLD RECYCLING MIX DESIGN REQUIREMENTS for Emulsified Asphalts

Test Method	Criteria	Property
High Temperature Validation		
Indirect Tensile Strength [m] AASHTO T 283 (ASTM D4867)	Minimum 45 psi (310 kPa) [f,g]	Cured Strength
Marshall Stability [m] AASHTO T 245 (ASTM D6927)	Minimum 1,250 lb. (5,560 N) [g]	Cured Stability

Tensile Strength Ratio/Retained Marshall Stability based on Moisture Conditioning [m] AASHTO T 283 (ASTM D4867) AASHTO T 245 (ASTM D6927)	Minimum 0.70 [i]	Resistance to Moisture Induced Damage
Raveling Test of Cold Mixed Bituminous Mixtures [n] ASTM D7196	Maximum 7.0% loss [n]	Resistance to Raveling
Evaluation of Existing Binder		
Recovery of Binder from RAP [o] AASHTO T 319 (ASTM D5404) or ASTM D1856	Used for Penetration Testing	Recovery of Binder
Penetration of Bituminous Materials AASHTO T 49 (ASTM D5)	Report Only	Softness of Existing Binder

NOTES:

[m] If the ambient temperature during construction is expected to be above 85 °F (30 °C) the following testing shall be included: 0.25 to 0.5% shall be deducted from the optimum emulsified asphalt recycling agent content determined by virtue of the testing performed as outlined in Table 1. Six specimens shall be prepared in accordance with **note c** above, with the exception that the mixing and compaction temperature shall be 104 ± 4 °F (40 ± 2 °C). The specimens shall be tested in accordance with **notes e and h** above, with the exception that molds shall be pre-heated to 104 ± 4 °F (40 ± 2 °C).

[n] If the ambient temperature during construction is expected to be above 85 °F (30 °C) the following testing shall be included: 0.25 to 0.5% shall be deducted from the optimum emulsified asphalt recycling agent content determined by virtue of the testing performed as outlined in Table 1 and two specimens shall be prepared in accordance with ASTM D7196 at the actual or medium RAP gradation. Compaction temperature shall be 104 ± 2 °F (40 ± 1 °C). Immediately after compaction the specimens shall be conditioned at 77 ± 2 °F (25 ± 1 °C) at 50% relative humidity. Procedures and calculations in accordance with ASTM D7196 shall be followed. The average percent mass loss of the two specimens shall be reported, even if the replicate samples differ by more than 0.5%.

User Note: The use of the raveling test in combination with other tests in this procedure may be protected by one or more of the following US patents 6,599,057, 7,275,890, and 7,455,476. For more information, contact Road Science at www.roadscience.net or call 918-960-3800. Alternatively, do not perform the raveling test or replace it with an alternate test.

[o] 3.3 lbs. to 6.6 lbs. (1,500 to 3,000 g) of RAP shall be used to recover binder.

4.3 Report

The report shall contain the following minimum information:

- RAP binder content
- Gradation of RAP, and corrective aggregate when required
- Density, maximum specific gravity, air void content, indirect tensile strength or Marshall stability, level of saturation, retained stability or tensile strength ratio at each emulsified asphalt recycling agent content
- Recommended water content range as a percentage of dry RAP
- Optimum emulsified asphalt recycling agent content as a percentage of dry RAP

- Emulsified asphalt recycling agent designation, supplier name and location, emulsified asphalt residue asphalt content and certificates of compliance
- Amount and type of recycling additive as a percentage of dry RAP
- Ratio of asphalt content of recycling agent to cement
- Application means of recycling agent
- Emulsified asphalt recycling agent supplier name and location and certificates of compliance
- Compaction method used to prepare strength or stability specimens
- Raveling test results including emulsified asphalt recycling agent content, curing conditions and percent loss, if performed
- RAP coating test results
- Density, air void content, indirect tensile strength or Marshall stability, retained stability or tensile strength ratio at recommended moisture, emulsified asphalt recycling agent and recycling additive contents

The following optional test results shall be reported if applicable:

- High temperature validation results including emulsified asphalt recycling agent content, corresponding density, air void content, indirect tensile strength or Marshall stability, level of saturation, retained stability or tensile strength ratio
- Raveling test results including emulsified asphalt recycling agent content, curing conditions and percent loss, if performed.
- Penetration of recovered binder from the RAP